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16. ABSTRACT

Recently, the United States Congress enacted laws that provide for protection and monitoring of groundwater quality. Many attempts to monitor groundwater quality have shown that such monitoring is usually costly and difficult because groundwater is relatively inaccessible and the chemical behavior of pollutants in the subsurface is very complex. In response, a monitoring methodology has been developed under sponsorship of the U.S. Environmental Protection Agency. This methodology has excellent potential for application at State and local levels of Government. The methodology is briefly discussed and the published reports that contain details on it are summarized and referenced.

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JOURNAL ARTICLE

MONITORING GROUNDWATER QUALITY

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Groundwater is a major natural resource in the United States. It accounts for more than 258 million cubic meters (68 billion gallons) per day of the nation's fresh water supply.[1] Approximately half of the nation's population receive their drinking water from groundwater sources.[2] The groundwater reservoirs in North America contain 2000 to 3000 times as much water as is present in the river channels at any one time.[3] Furthermore, groundwater discharges into rivers and streams constitute a substantial part of the streamflow.

Recent emphasis on the need to protect groundwater quality has been provided by the U.S. Congress through the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) and the Safe Drinking Water Act of 1974 (Public Law 93-523). These laws give the U.S. Environmental Protection Agency (EPA) a major responsibility for preventing contamination of groundwater resources, and they bring a new focus to the need for predictive groundwater monitoring.

Present groundwater monitoring programs, at both the Federal and State level, were designed mainly to assess the quantity and quality of groundwater available for a particular use. To prevent contamination of groundwater resources, the monitoring program must do more than this. It must provide a systematic approach for detecting and delineating groundwater pollution before the pollution reaches the points of groundwater use, and preferably before the pollutants enter the ground. It must focus on identifying the pollution sources, specific pollutants, and their respective mobilities through the hydrogeologic system. Whether or not the pollutants reach a point of water use can no longer be the determining factor as to what constitutes groundwater pollution.

Such a systems approach to predictive groundwater monitoring has now been developed by EPA. (Contract No. 68-01-0759 between the U.S. Environmental Protection Agency and the General Electric – TEMPO Center for Advanced Studies, Santa Barbara, California 93101.) It provides for a systematic methodology which focuses on identification and quantification of the most important pollution sources and causes, and also provides guidelines for implementing a cost-effective monitoring program to protect the nation's groundwaters.

The complexities in assessing groundwater quality stem from several factors. First, the numbers and kinds of contaminants entering groundwater are rapidly accelerating because recent legislation restricts discharge of waste effluents and substances into surface waters and the atmosphere, and, consequently, these are deposited on the land surface or into the subsurface. Second, the movement of pollutants in the ground is very difficult to determine. Millions of years of uplifting and subsequent erosion of the earth's surface have resulted in complicated groundwater paths. Third, the combinations of pollutants and subsurface geologic conditions that may be encountered across the United States are so large that a total systems approach to monitoring groundwater quality is needed.

Because groundwater is not readily accessible, the traditional approach to its monitoring has centered around and emphasized the drilling and sampling of test wells, analyzing the collected samples, and evaluating the results. This approach is quite expensive in terms of dollars and manpower. Consequently, groundwater monitoring has often been judged economically unfeasible.

The new approach developed by EPA is detailed in a report entitled, "Monitoring Groundwater Quality: Monitoring Methodology" (EPA-600/4-76-026, NTIS PB-256068/AS).[4] (NTIS – National Technical Information Service, Springfield, Virginia

WATER QUALITY BULLETIN 2:1, pp 11-14, January 1977

TABLE 1. MAJOR SOURCES AND CAUSES OF GROUNDWATER POLLUTION AND METHODS OF WASTE DISPOSAL [4]

SOURCE	CATEGORY			COMMON METHOD OF DISPOSAL						
	Point	Line	Diffuse	Percolation Pond	Surface Spreading and Irrigation	Seepage Pits and Trenches	Dry Stream Beds	Landfills	Disposal Wells	Injection Wells
Municipal										
Sewer Leakage	X	X		NOT APPLICABLE						
Sewage Effluent	X	X	X	X	X		X		X	
Sewage Sludge	X		X		X	X		X		
Urban Runoff	X	X	X	X	X		X		X	
Solid Wastes	X				X			X		
Lawn Fertilizers			X		X					
Agricultural										
Evapotranspiration and Leaching (Return Flow)			X		X					
Fertilizers			X		X					
Soil Amendments			X		X					
Pesticides and Herbicides			X		X					
Animal Wastes (Feedlots and Dairies)	X		X	X	X	X		X		
Stockpiles	X			NOT APPLICABLE						
Industrial										
Cooling Water	X		X	X					X	
Process Waters	X			X					X	X
Storm Runoff	X		X	X	X		X		X	
Boiler Blowdown	X			X					X	
Stockpiles	X			NOT APPLICABLE						
Water Treatment Plant Effluent	X			X				X	X	
Hydrocarbons	X			X					X	X
Tanks and Pipeline Leaks	X	X		NOT APPLICABLE						
Oilfield Wastes										
Brines	X	X	X	X	X	X	X			X
Hydrocarbons	X			X					X	X
Mining Wastes	X	X	X	X			X	X	X	X
Miscellaneous										
Polluted Precipitation and Surface Water		X	X	NOT APPLICABLE						
Septic Tanks and Cesspools			X		X	X		X		
Highway Deicing		X		NOT APPLICABLE						
Seawater Intrusion			X	NOT APPLICABLE						

22161, where reports may be ordered by their PB number.) The methodology consists of a series of procedural steps arranged in chronological order. The steps are:

1. Select area or basin for monitoring.
2. Identify pollution sources, causes, and methods of waste disposal.
3. Identify potential pollutants.
4. Define groundwater usage.
5. Define hydrogeologic situation.
6. Study existing groundwater quality.
7. Evaluate infiltration potential for wastes at the land surface.
8. Evaluate mobility of pollutants from the land surface to the water table and the chemical changes the pollutants undergo.
9. Evaluate attenuation of pollutants in the saturated zone.
10. Prioritize sources and causes.
11. Evaluate existing monitoring programs.
12. Establish alternative monitoring approaches.
13. Select and implement the monitoring program.
14. Review and interpret monitoring results.
15. Summarize and transmit monitoring information.

While these steps are sequentially logical, lack of information for any one step need not be an obstacle to proceeding with the next step. Information refinement, at first, is much less important than comprehensive coverage, no matter how preliminary or approximate.

For example, in step 2, which involved identifying pollution sources, causes, and methods of waste disposal, the basic initial information might be summarized as shown in Table 1. Likewise, under step 3, where potential pollutants are identified, the initial effort will involve identification of types of pollutants by source, as shown in Table 2. After the monitoring area to be considered is defined, simultaneous efforts on steps 2 to 10 can proceed without strict adherence to their numerical order.

Although the "Monitoring Methodology" report is self-contained,

four other reports have been published in a Monitoring Groundwater Quality series. These contain supplemental data, information, and examples. They are:

Monitoring Groundwater Quality: Methods and Costs, EPA-600/4-76-023.

This report summarizes specific techniques available for monitoring groundwater quality together with detailed estimates, where available, of their costs.

Monitoring Groundwater Quality: Data Management, EPA-600/4-76-019, (NTIS — PB-255492).

This report examines the requirements of a groundwater quality data management information system, reviews existing systems, and identifies how existing capabilities can be utilized for a groundwater quality monitoring program.

Monitoring Groundwater Quality: Economic Framework and Principles, EPA-600/4-76-045.

This report reviews the existing institutional and legal structure pertaining to groundwater pollution, presents a hydrogeologic case study as a framework for discussion of economic issues of groundwater monitoring, and analyzes economic principles pertaining to groundwater pollution monitoring.

Monitoring Groundwater Quality: Illustrative Examples, EPA-600/4-76-036.

This report is designed to show by example selected source-specific and pollutant-specific monitoring procedures. It describes five case histories of actual groundwater pollution.

In addition to the five reports in this series, six other reports were prepared as a part of the same study. They serve as corollary contributions to the monitoring methodology. These six are:

Groundwater Pollution Features of Federal and State Statutes and Regulations
EPA-600/4-73-001a (NTIS — PB-232116/461)

Polluted Groundwater: Some Causes, Effects, Controls, and Monitoring
EPA-600-4/73-001b (NTIS — PB-232117/WP)

TABLE 2. MAJOR SOURCES OF GROUNDWATER POLLUTION AND TYPES OF POLLUTANTS [4]

SOURCE	TYPE OF POLLUTANT					
	Physical	Inorganic Chemical	Trace Elements	Organic Chemical	Bacteriological	Radiological
Municipal						
Sewer Leakage	Minor	Primary	Secondary	Primary	Primary	Minor
Sewage Effluent	Minor	Primary	Secondary	Primary	Primary	Minor
Sewage Sludge	Minor	Primary	Primary	Primary	Primary	Minor
Urban Runoff	Minor	Secondary	Variable	Primary	Minor	Minor
Solid Wastes	Minor	Primary	Primary	Primary	Secondary	Minor
Lawn Fertilizers	Minor	Primary	Minor	Minor	Minor	Minor
Agricultural						
Evapotranspiration and Leaching	Minor	Primary	Minor	Minor	Minor	Minor
Fertilizers	Minor	Primary	Secondary	Secondary	Minor	Minor
Soil Amendments	Minor	Primary	Minor	Minor	Minor	Minor
Pesticides	Minor	Minor	Minor	Primary	Minor	Minor
Animal Wastes (Feedlots and Dairies)	Minor	Primary	Minor	Secondary	Primary	Minor
Stockpiles	Minor	Primary	Minor	Variable	Variable	Minor
Industrial						
Cooling Water	Primary	Minor	Primary	Minor	Minor	Minor
Process Waters	Variable	Primary	Primary	Variable	Minor	Variable
Storm Runoff	Minor	Secondary	Variable	Primary	Minor	Minor
Boiler Blowdown	Primary	Secondary	Primary	Minor	Minor	Minor
Stockpiles	Minor	Primary	Variable	Variable	Minor	Variable
Water Treatment Plant Effluent	Minor	Primary	Secondary	Minor	Minor	Minor
Hydrocarbons	Secondary	Secondary	Secondary	Primary	Minor	Minor
Tank and Pipeline Leakage	Variable	Variable	Variable	Variable	Minor	Variable
Oilfield Wastes						
Brines	Primary	Primary	Primary	Minor	Minor	Minor
Hydrocarbons	Secondary	Secondary	Secondary	Primary	Minor	Minor
Mining Wastes	Minor	Primary	Primary	Variable	Minor	Variable
Miscellaneous						
Polluted Precipitation and Surface Water	Variable	Variable	Variable	Variable	Variable	Variable
Septic Tanks and Cesspools	Minor	Primary	Minor	Secondary	Primary	Minor
Highway Deicing	Minor	Primary	Minor	Secondary	Minor	Minor
Seawater Intrusion	Primary	Primary	Primary	Minor	Minor	Minor

Polluted Groundwater: A Review of the Significant Literature
EPA-680-4/74-001 (NTIS — PB-235556/8WP)

Polluted Groundwater: Estimating the Effects of Man's Activities
EPA-680-4/74-002 (NTIS — PB-241078)

Rationale and Methodology for Monitoring Groundwater Polluted by Mining Activities
EPA-680-4/74-003 (NTIS — PB-241402)

Monitoring Disposal-Well Systems
EPA-680-4/75-008 (NTIS — PB-246214/AS)

In conclusion, the monitoring methodology presented in the cited reports should be of value to monitoring agencies at all levels of government because for the first time they are provided with a structured approach for implementing a monitoring program. Applying the described procedures and techniques to a prescribed area will provide the most cost-effective method for assessing groundwater quality. The predictive capability of this approach will enable planners and control officials to make decisions and take actions that will protect public health as well as the future quality of this vital resource.

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